The Potential for a Ka-band (32 GHz) Worldwide VLBI Network

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Abstract

Ka-band (32 GHz, 9mm) Very Long Baseline Interferometric (VLBI) networking has now begun and has tremendous potential for expansion over the next few years. Ka-band VLBI astrometry from NASA's Deep Space Network has already developed a catalog of ∼470 observable sources with highly accurate positions. Now, several antennas worldwide are planning or are considering adding Ka-band VLBI capability. Thus, there is now an opportunity to create a worldwide Ka-band network with potential for high resolution imaging and astrometry. With baselines approaching a Giga-lambda, a Ka-band network would be able to probe source structure at the nano-radian (200 μas) level (100X better than Hubble) and thus gain insight into the astrophysics of the most compact regions of emission in active galactic nuclei. We discuss the advantages of Ka-band, show the known sources and candidates, simulate projected baseline (uv) coverage, and discuss potential radio frequency feeds. The combination of these elements demonstrates the feasibility of a worldwide Ka network within the next few years!

1. Introduction

Ka-band is ∼32 GHz or 9 mm wavelength. It is found between the 22 GHz water line and the 60 GHz O_2 line. At Ka-band sources tend to be core dominated because the extended structure in the jets tends to fade away with increasing frequency. There are 21 VLBI antennas worldwide that either have, are planning, or are considering Ka-band capability (Fig. 1 and Tables 1, 2).

Advantages of Ka: There are several advantages of Ka-band. The short 9 mm wavelength and long baselines approaching a Giga-λ allow for resolution approaching 200 μas. The sources are more compact than at X-band which should reduce source structure effects and core shifts. Ka-band allows for higher telemetry rates for spacecraft communications by +5 to +8 dB as well as smaller lighter RF spacecraft systems. Ka-band avoids S-band RFI issues. Ionosphere and solar plasma effects are reduced by a factor of 15 compared to X-band, thus allowing observations closer to the Sun or the Galactic center.

Disadvantages of Ka: Because Ka-band is near the 22-GHz water line, Ka-band is more weather sensitive and has higher system temperatures than comparable systems at X-band. Because Ka-band has a shorter wavelength than X-band, coherence times are shorter thus limiting the potential for longer integrations on source. Some sources are weaker or resolved. Antenna pointing is more difficult, but Rochblatt *et al* (2007) have demonstrated Ka-band blind pointing over the full sky for large 34-m antennas. The net effect is to reduce system sensitivity, but advances in recording technology are rapidly compensating (e.g. Whitney, 2012).

2. X/Ka-band radio catalog

A catalog of $\sim$ 470 Ka-band sources exists. Based on comparisons to the S/X-based ICRF2 (Ma *et al*, 2009) accuracy is 200 to 300 μas (García-Miró *et al*, 2012; Jacobs *et al*, 2011). The south polar cap is not yet covered, but a pilot project is underway (Horiuchi *et al*, 2012) using 144 of the 498 candidates identified by Sotuela *et al* (2011). Thus sufficient sources are available for geodesy, global astrometry, and differential VLBI phase calibration.

3. Network geometry and uv coverage

How strong is the potential for imaging? To answer this question, we made simulations (AIPS, AU/NSF) of the set of projected baseline lengths generated as the Earth rotates (uv coverage). The Euro sub-net can cover out to $\sim$600 Mega-lambda. The south Pacific sub-net to $\sim$500 Mega-lambda, with both arrays having potential for almost a Giga-lambda if outriggers in the U.S. and/or Japan are added. Fig. 2a shows uv coverage for the Euro net (Tab. 1) for a circumpolar source at Dec= $+75°$ Fig. 2b shows the south pacific sub-net with Japanese outriggers added to extend North-South coverage to $\sim$ 800 M-lambda. In summary, there is potential for imaging at the few 100 μas level.

4. Feeds for X/Ka and S/X/Ka-bands

Ka-band capable feeds are a key element required for a functioning Ka network. NASA's Deep Space Network (DSN) has had X/Ka feeds for over a decade in its 34-m antennas (e.g. Chen *et al*, 1993 and 1996; Stanton *et al*, 2001). More recently, several designs have appeared for 12-m class antennas intended for geodesy in the IVS-2010 era. Hoppe & Reilly (2004) designed an X/Ka feed for the (then) Patriot 12-m antenna. Twin Telescopes Wettzell (TTW) is designing an S/X/Ka feed (Goldi, 2009). The RAEGE project is also designing an S/X/Ka feed (Tercero, 2012; and López-Pérez *et al*, 2012). Thus there are sufficient feed designs to equip antennas at Ka-band. As a proof-of-concept, the first Ka-band fringes outside the DSN were obtained on the DSS-55 to Effelsberg baseline on 2011 day-of-year 223 with source OT 081 recording at 448 Mbps.

5. Conclusions and Future Prospects

Ka-band (32 GHz, 9mm) Very Long Baseline Interferometric (VLBI) global networking is feasible within the next few years. Ka-band VLBI astrometry from NASA's Deep Space Network has already developed a catalog of observable sources with highly accurate positions. Now, a number of antennas worldwide are planning or are considering adding Ka-band VLBI capability. Thus, there is now an opportunity to create a worldwide Ka-band network capable of high resolution imaging and astrometry. With baselines approaching a Giga-lambda, a Ka-band network would be able to probe source structure at the nano-radian (200 μas) level (100X better than Hubble) and thus gain insight into the astrophysics of the most compact regions of emission in active galactic nuclei. We discuss the advantages of Ka-band, show known sources and candidates, simulate uv coverage, and discuss potential RF feeds. First Ka fringes outside the DSN were demonstrated in 2011. Ka fringe tests from the DSN to TTW and RAEGE are being planned late 2012. All these things demonstrate that a worldwide Ka-band network is feasible within the next few years!

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Table 1. Ka-band European VLBI sub-net

Station	Location	Diameter	Bands	Time frame
Robledo	Spain	34	S,X,Ka	now
Cebreros	Spain	35	X,Ka	now
Effelsberg	Germany	100	Ka	now
Wettzell	Germany	13	S,X,Ka	2012
RAEGE				
Yebes	Spain	13	S,X,Ka	2013
Canaries	Spain	13	S,X,Ka	2013
Santa Maria	Azores	13	S,X,Ka	2014
Flores	Azores	13	S,X,Ka	2014
Russian sub-net				
Kazan	Russia	12	S,X,Ka	TBD
Kislovodsk	Russia	12	S,X,Ka	TBD

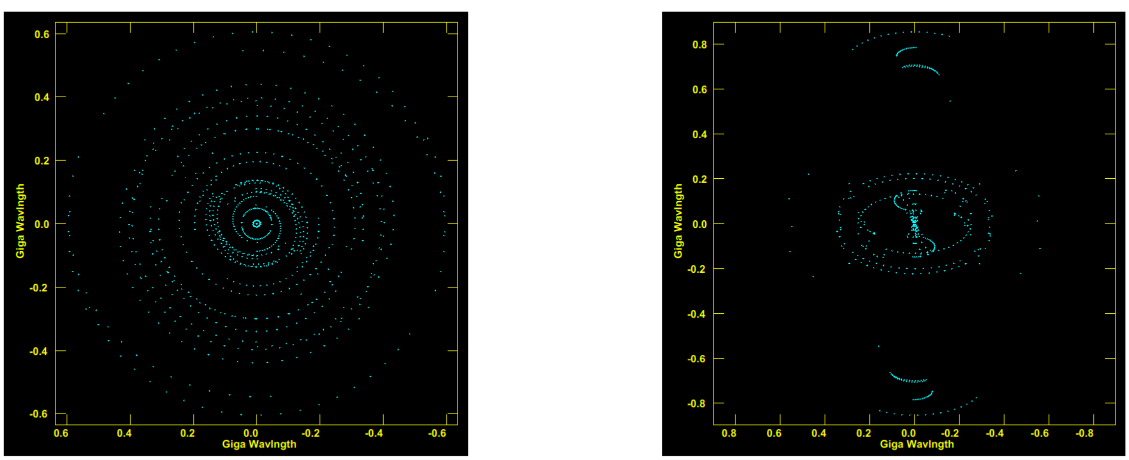
Effelsberg supports only linear polarization

Table 2. Ka-band Pacific VLBI sub-net

Station	Location	Diameter	Bands	Time frame
Tidbinbilla	Australia	34	X,Ka	now
Narrabri	Australia	6x22	Ka	now
Mopra	Australia	22	Ka	now
Parkes	Australia	12	S,X,Ka	TBD
Auscope+NZ				
Hobart	Australia	12	S,X,Ka	now/TBD
Katherine	Australia	12	S,X,Ka	now/TBD
Yaragadee	Australia	12	S,X,Ka	now/TBD
Warkworth	New Zealand	12	S,X,Ka	now/TBD
N. Pacific Outriggers				
Kashima	Japan	34	Ka	now
Usuda	Japan	45	S,X,Ka	2018
E. Pacific Outrigger				
Goldstone	California	34	X,Ka	now

Mopra & Narrabri support only linear polarization

Figure 1. Ka-band Station Distribution. Note clusters in Europe and Australia. *Credit: Google maps*



a. European network: source at Dec $+75°$.

b. S. Pacific net + Japan outrigger: Dec $-30°$

Figure 2. Ka-band Network UV coverage examples.